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SUPERSONIC SOUNDING INSTRUMENTS AND METHODS

By Joseph M. Caldwell, Assoc. M. ASCE

HYDRAULICS DIVISION

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PAPERS

SUPERSONIC SOUNDING INSTRUMENTS AND METHODS

By Joseph M. Caldwell,[1] Assoc. M. ASCE

Synopsis

A brief history of the development of echo sounders is given. The distinguishing features of various basic types of sounders are discussed, together with the elements of echo sounder operation. The inherent limitations of echo sounding are pointed out with certain supporting data to enable some of the limitations to be determined on a quantitative basis. The use of echo sounders over firm sand bottoms and over soft mud bottoms is discussed, and factual data are introduced to show the "average" error to be expected in repeated soundings of the same profile. A comparison is made between soundings of a selected profile as obtained by echo sounders and by lead line, and the comparative results from the two methods are given in considerable detail.

Introduction

The desire to increase the rate of making soundings in hydrographic survey work has probably existed since men first began to chart the navigable waters of the earth. The first recorded suggestion that underwater sound waves might be used for such a purpose was made by a French physicist, Dominique François Jean Arago, in 1807. Although numerous attempts were made during the remainder of the century to evolve a method of measuring depths by sound waves, 100 years elapsed from the time of Arago before anyone was successful in perfecting even a crude echo sounder. These first successful developments were made, strangely enough, not as echo sounders but as iceberg detectors following the sinking of the *S. S. Titanic* in 1912.

With the incidence of World War I and submarine warfare, knowledge of underwater acoustics was increasing rapidly and by 1925 several forms of echo sounders had been put into use. One of the most promising developments, in 1925, was a device that enabled extremely short time intervals to be measured

Note.—Written comments are invited for publication; the last discussion should be submitted by June 1, 1951.

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accurately, and to be converted automatically to a depth measurement. This development adapted the echo sounder to shallow water hydrographic studies, and the feature was incorporated in Fathometer model No. 312 by the United States Coast and Geodetic Survey (USCGS). The No. 312 Fathometer was still used on some ships of the USCGS as late as 1941.

Two of the principal users of echo sounders for hydrographic survey work in the United States are the Corps of Engineers, United States Department of the Army (USED), and the USCGS, the former being concerned chiefly with inland waters and the latter, with coastal waters. The remainder of this paper will be devoted, for the most part, to the experiences of these two organizations with echo sounders.

Types of Sounders

There are at least twenty-five or thirty features of construction and operation which make one type of sounder different from another. However, three of the most important features that identify a particular sounder are: (*1*) The portable or fixed instrument; (*2*) the visually indicating or recording instrument; and (*3*) the frequency of the signal, or note used as the sound signal.

1. Portable or Fixed Instrument.—Generally, the portable instruments weigh about 200 lb and can be moved from craft to craft with little difficulty. The fixed installations are much more massive (approximately 800 lb) and are more or less permanently mounted aboard a suitable survey craft.

2. Visually Indicating or Recording Instrument.—The indicating instruments give only a transient indication of depth and therefore require an attendant to record the data. The recording instruments, on the other hand, furnish a permanent record which is obviously advantageous in hydrographic survey work. Most of the instruments manufactured in the United States are of the recording type.

3. Frequency of the Signal or Note Used As the Sound Signal.—If the sound note is in the ordinary, audible, musical range the instrument is considered to be a sonic sounder. If the note is near the top or above the audible sound range (14,000 cycles per sec or more), it is considered to be a supersonic instrument. The advantages of the two frequency ranges are discussed subsequently in this paper.

Principles of Operation

Briefly stated, the essential components of an echo sounder are a signal generator, a signal transmitter, an echo receiver, and an amplifier-recorder. The first and last items are frequently put in the same box and are referred to simply as the sounder. The other two items are usually mounted together or near each other, and the combination is called "the transceiver." The sequence of operations in obtaining a sounding is as follows:

a. The signal generator initiates by electronic methods a short, but strong, electrical impulse which is sent to the signal transmitter.

b. The signal transmitter, which is mounted underwater, converts the electrical impulse to a mechanical vibration or sound wave which is directed toward the bottom.

c. The sound wave reaches the bottom and is reflected as an echo.

d. This echo is detected by the signal receiver which is also mounted underwater. The receiver converts the echo into an electrical signal which is sent on to an electronic amplifier.

e. The electronic amplifier receives the signal and amplifies it sufficiently to make it discernible on a suitable indicator or recorder.

f. The indicator or recorder receives the signal from the amplifier, measures the time elapsed from the generation of the sound signal to the return of the echo, converts this time interval to equivalent depth of water, and furnishes an indication or record of this depth.

It should be realized that the foregoing steps are repeated automatically by the instrument so that, in shallow water, soundings may be taken at the rate of 100 per min or more.

Limitations in Echo Sounders

Several factors limit the application and accuracy of the instruments. For instance, the speed of the survey craft must be slow enough to avoid entraining air under the bow which will find its way under the vessel. Air bubbles will form a sound block and may cause the record to show erroneous readings, or to be lost entirely.

Another limitation is the angular size of the sound cone. Generally, the surveyor would like to measure the water depth directly under the hull. However, the sound signal sent out by the sound transmitter is in the form of a cone whose central angle, a, varies with the radius, r, of the transmitter plate and the frequency of the sound signal. Its value can be calculated from the formula:

$$\sin \tfrac{1}{2} a = 0.61 \frac{L}{r} \ldots\ldots\ldots (1)$$

in which L is the wave length in water of the sound signal used. The significance of the frequency is illustrated in Table 1, which is based on computations for a sound transmitter plate 12 in. in diameter ($r = 6$) in sea water at 37°F, or in fresh water at 65°F.

TABLE 1.—Effect of Frequency on the Directional Character of a Sound Beam

Frequency, in cycles per second	Dimensions of Sound Cone	
	Angle, a	Ratio, diameter to depth
(1)	(2)	(3)
8,000[a]	94°	2.14
16,000[b]	43°	0.79
32,000[b]	21°	0.37
64,000[b]	10½°	0.18

[a] Sonic. [b] Supersonic.

One common type of sounder for which $r = 0.5$ ft operates with a frequency of about 16,000 cycles per sec for the sound signal, giving a wave length of about 0.30 ft in fresh water at 65°F. If these values are substituted in Eq. 1, the sound cone angle is computed to be about 43°. With this size of sound cone, the area scanned or covered by the cone at any instant has a diameter of about eight tenths of the depth of the water below the sound transmitter. For instance, if the depth below the transmitter is 20 ft, the area being scanned by the sound cone has a diameter of about 16 ft, and the instrument will indicate

the distance to the object within the sound cone nearest the transceiver. Where the hydrography is relatively flat, this fact is of no great concern, but it may introduce considerable error where steep underwater gradients are encountered. In fact it can be shown that the aforementioned sounder will indicate a depth approximately 6% less than the true depth at the junction of a flat bottom and a 1:2½ slope; under these conditions this difference amounts to an error of about 1 ft in 20-ft depth of water. This 6% error would be evident at all points over the 1:2½ slope and, of course, would become greater for steeper slopes, being in the order of 12% for a 1:1½ slope. For higher sound signal frequencies, this inherent error would tend to become less, whereas for lower frequencies it would tend to become somewhat greater. As an example, consider Fig. 1, in which point *E* denotes an echo sounder having a frequency of 16,000 cycles per sec, and in which $r = 0.5$ ft. Although the true depth under the echo sounder is line EB and the shortest distance from the echo sounder to the bottom is ED, the depth recorded by the echo sounder will be line EC, since this is the shortest distance to the bottom within the sound cone.

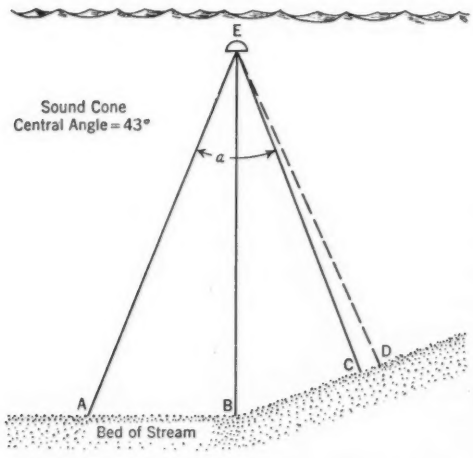

FIG. 1.—EFFECT OF BOTTOM SLOPE ON THE ACCURACY OF RECORDING BY ECHO SOUNDER

Another limitation in the use of echo sounders is the strength of the echo necessary to enable the amplifier-recorder to detect the echo and give a usable record. When working in shallow water, say, less than 200 ft, and over a clean rock or sand bottom, a sharp, well-defined echo is returned to the surface. However, the top layers of an unconsolidated mud bottom may return such a faint echo that the sounder may not detect this initial echo; instead the sounder may detect, as the bottom, a point down in the material which has become sufficiently consolidated to return a usable echo. To complicate this picture further, this discernible echo point can be shifted up or down, in some cases, by increasing or decreasing the gain on the amplifier. In such cases the recorder chart can be made to show a noticeable spread of depth when operating over a single point simply by changing the amplifier gain control.

Another basic limitation in the operation of echo sounders is the absorption of sound energy by the water. As a result of this absorption there is a limit to the depth to which the sounder can operate because of the loss of strength of the sound signal and the echo. This factor is of little concern in inland and coastal work, however, as practically all sounders will work satisfactorily to depths of 500 ft or less. It is of real concern, of course, in charting the great ocean basins. In this connection, it should be noted that the higher the frequency is, the greater will be the absorption of the sound by the water. This

characteristic, in effect, controls the upper limit of the frequency that is practicable to use in various depths.

Generally, the supersonic sounders are preferred because of the directional character of the sound beam and because of their relative freedom from the influence of random engine noises and similar disturbances.

Adoption of Echo Sounders

The USCGS first used echo sounders in 1923 when the survey ship *Guide* was equipped with an early model for a trip from Norfolk, Va., to San Diego, Calif. Reliance on these instruments has increased steadily since that time and all USCGS survey ships are either equipped with fixed sounders or are adapted to utilize portable sounders. It is the basic sounding method used at present

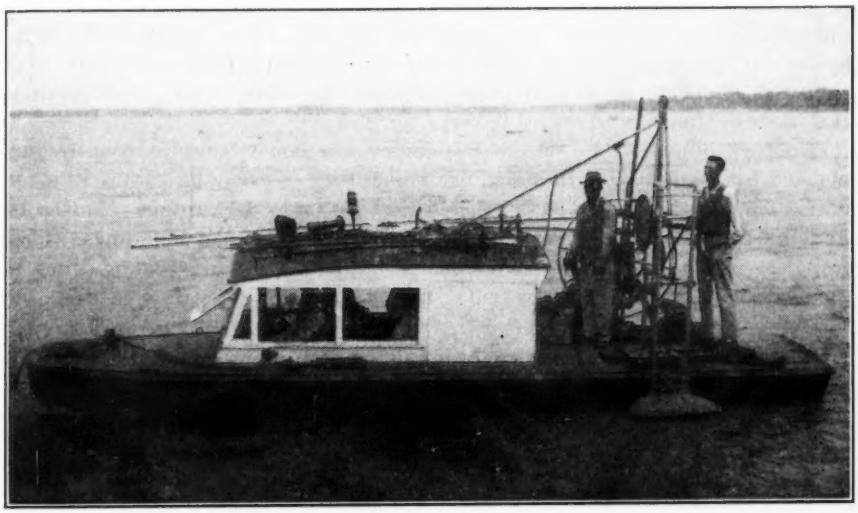

Fig. 2.—"Transceiver" for Portable Echo Sounder Mounted on a Survey Boat of the Vicksburg (Miss.) District, Corps of Engineers

by that organization. Until 1939, all instruments used by the USCGS had been of the indicating type. In 1939, a recording sounder of British manufacture was installed on one of its ships, and the popularity of the recording type has increased rapidly since that time.

The USED began to use echo sounders in the early 1930's and their use by the Corps has increased steadily since that time. At present (1950) the greater part of the hydrographic work of the USED is conducted with the aid of supersonic echo sounders operating at frequencies of the order of 15,000 cycles per sec. The portable recording sounder is in general use in the USED because it is best adapted to the wide variety of hydrographic work to which any survey crew may be assigned from time to time. Fig. 2 shows an installation of a portable sounder transceiver on a USED craft; the transceiver is submerged during actual sounding operations.

It should not be inferred from the foregoing statements that the echo sounder has met with immediate acceptance by those engaged in hydrographic survey work. Like most new instruments and methods, the sounder has had to earn its way into widespread acceptance. Some opposition was justified, principally because of various imperfections and limitations in the earlier models; yet, part of the opposition was more of a personal reluctance to adopt the new, rather than any coldly logical objection. When it is remembered that, before the introduction of the echo sounder, the techniques of hydrographic survey crews had been more or less stabilized for many years, some of the objections that arose to the use of the sounder are understandable. These older techniques of the sounding line and the sounding pole were simple and well established, the survey crews understood them, and the members of the crew felt well qualified and relatively secure in their jobs. When suddenly confronted with a complicated, electrical device with vacuum tubes, pigtail resistances, and condensers the members of the survey crew suddenly felt themselves unqualified and insecure. Thus, when the new echo sounder broke down or showed evidence of giving an erroneous set of soundings, the crew was all too ready to condemn it as a waste of time and to return to using the lead line.

Another objection to the echo sounder has come from the contractors engaged by the USED. In a significant majority of dredging contracts made since 1935 the contractors have insisted that payment for yardage removed be made on the basis of lead line soundings as opposed to echo soundings. This prejudice is gradually being overcome as experience shows that a properly operated sounder will give a fair and representative picture of the hydrography.

Field Experience with Sounders

The echo sounder is used as a navigation aid, for hydrographic surveying purposes, and by deep-sea fishing fleets for locating schools of fish. Its use as a navigation and fishing aid requires a lower degree of accuracy than does the hydrographic survey work. Since commercial craft interested in the sounder from a fishing and navigational standpoint are much more numerous than hydrographic survey parties, it is only natural that the manufacturers have been inclined to build an instrument adapted primarily to commercial needs and secondarily to surveying needs. Nevertheless, the sustained interest and encouragement of the USCGS, the United States Navy, and the USED, combined with the inherent impulse of the manufacturers to do a good job, have resulted in the production of sounders very well adapted to hydrographic surveying.

Assuming that a fairly skilled operator is employed, the supersonic sounders presently being used by the USED are rated as having an accuracy of $\pm$ 6 in. at a 50-ft depth for the portable model, and $\pm$ 3 in. at a 50-ft depth for the nonportable or fixed model. It should be noted that the accuracy is stated in inches at 50 ft and not as a percentage, because some errors in the sounder vary with the depth whereas others are independent of the depth. Thus, the error could be expected to be less at 10 ft than at 50 ft but not as much as the ratio of depths might indicate.

Conditions of Operation

In discussing the accuracy and dependability of echo sounder equipment as used by the USED, it appears advisable to divide the conditions of operation into three separate classifications, according to whether the sounder is operated over: (1) Sandy bottoms; (2) sandy beaches in wave action; or (3) soft mud bottoms.

1. Operation Over Sandy Bottoms.—Ordinary sand bottoms present an excellent reflecting surface to the sound wave in that they send a sharp, clear echo back to the receiver. The accuracy of echo soundings under these condi-

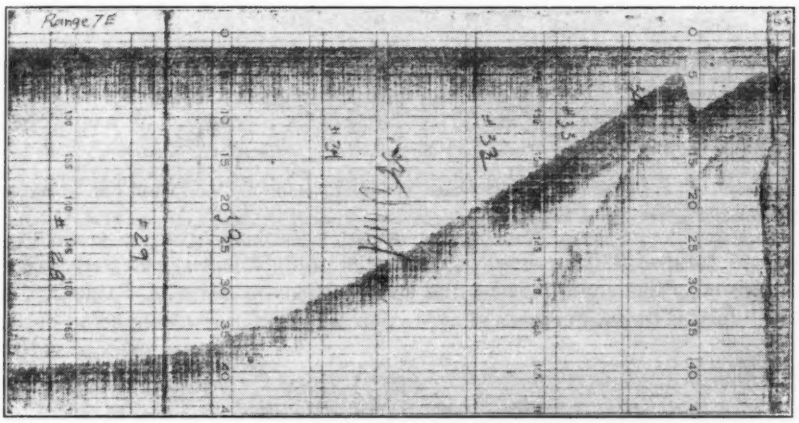

Fig. 3.—Echo Sounder Record Over Sand Bottom, with No Wave Action; Gulf of Mexico Near Pensacola, Fla.

tions is limited only by the stability of the speed control on the echo sounder and the proper assessment of the speed of sound through the underlying water. Tables are available which show the variation of sound speed with temperature and salinity which enables the proper adjustment or correction to be made for these variables. The speed controls on the instruments are fairly reliable although some improvement could probably be made on this feature.

In practice, the accuracy of an instrument is checked periodically during the day by a check bar suspended at a known depth below the sounder or by a carefully obtained lead line sounding on a firm bottom. As stated previously, the portable sounders used by the USED are rated at $\pm$ 6 in. in 50 ft of water whereas the more expensive fixed types are rated at $\pm$ 3 in. in 50 ft of water. Fig. 3 is an example of a record taken over a firm, sand bottom with no wave action.

For the most part, the accuracy of the echo sounder under these conditions is accepted by all users. The USCGS has used them almost exclusively since before 1935 and uses lead line soundings only to detect any gross misadjustment in the echo sounder.

2. Operation Over Sandy Beaches in Wave Action.—In connection with a hydrographic study at Long Branch, N. J., the Beach Erosion Board sounded a series of points from an amphibious truck using both a lead line and a portable

echo sounder. The soundings were taken with the truck moving into the waves with minimum headway, and a "fix" was burned on the chart at the instant the lead line was read for depth. The waves were running about 3 ft high at the

TABLE 2.—Comparison of Echo Sounder and Lead Line Sounding Over Sandy Beach (Portable Sounder and Ordinary Lead Line)

Description	15 Ft to 46 Ft			20 Ft to 29 Ft			30 Ft to 39 Ft			40 Ft to 49 Ft		
	No. of Soundings	Total of Differences	Average of Differences	No. of Soundings	Total of Differences	Average of Differences	No. of Soundings	Total of Differences	Average of Differences	No. of Soundings	Total of Differences	Average of Differences
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Echo Sounder Depths:												
Deeper than by lead line..	12	+5.1	+0.42	3	+1.0	0.3	2	+0.8	+0.4	7	+3.3	+0.5
Shallower than by lead line.	16	−6.5	−0.41	5	+2.1	0.4	3	−1.2	−0.4	7	−2.9	−0.4
Identical with lead line...	9	....	....	3	0	....	1	0	....	3	0	....
Sum of Differences:												
Numerical.....	37	11.6	0.32	11	3.1	0.3	6	2.0	0.3	17	6.2	0.4
Algebraic.....	37	−1.4	−0.04	11	−1.1	−0.10	6	−0.4	−0.07	17	0.4	+0.02

time. A total of 37 soundings in depths of from 15 ft to 46 ft were taken; a comparison of the soundings by the two methods is given in Table 2. This table indicates that differences of approximately 0.3 ft can be expected between

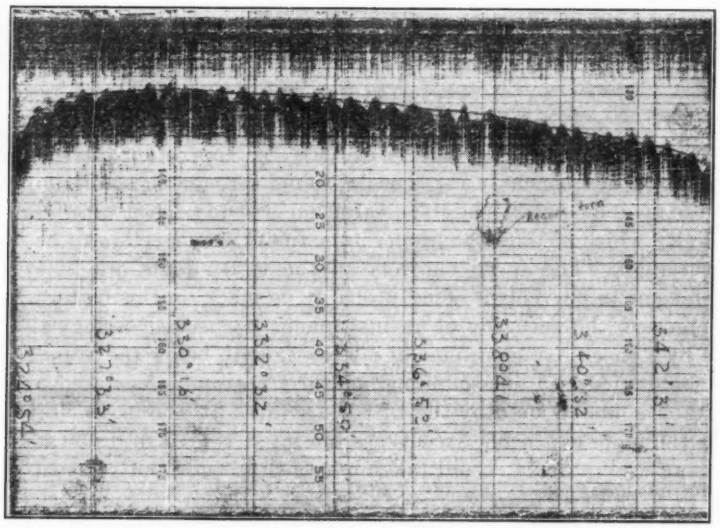

Fig. 4.—Echo Sounder Record Over Sand Bottom, with 3-Ft Surface Waves; Gulf of Mexico Near Pensacola, Fla.

lead line and echo sounder records at each cast of the line; however, the plus and minus differences so nearly balanced over the set of observations that the average difference was found to be only 0.04 ft, with the lead line averaging deeper than the sounder.

To study the effect of depth on the comparison, the data in Table 2 also show a comparison of these soundings in certain ranges of depth (from 20 ft to 30 ft, from 30 ft to 40 ft, and from 40 ft to 50 ft). The breakdown showed no significant difference from the over-all picture discussed in the preceding paragraph, the expected difference on each cast being in the order of from 0.3 ft to 0.4 ft, the average difference being in the order of from 0.1 ft or less.

It is recognized that this analysis was based on only 37 soundings, approximately half of which were made on one day and the other half on the next day. However, as no extraordinary care was taken in making the simultaneous soundings, it is believed that they are representative of the results that might be expected. In interpreting the sounder records, the Beach Erosion Board draws a line one half or one third the way between the troughs and crests, depending on the wave conditions; this line is then used as the bottom profile.

It is to be noted that the descrepancies between the lead line and echo sounder results have been designated as differences and not errors. It is difficult to assess the absolute accuracy of the two under such conditions, but it is believed that with the average difference so slight the echo sounder is probably the more consistently accurate of the two. In any event, it will permit more accurate readings with the survey boat traveling at higher speeds because the problem of plumbing the line does not enter the picture. Also, the record itself can be interpreted easily to compensate for the rise and fall of the survey boat with the passage of the wave crests; this is not possible with isolated lead line soundings.

An echo sounder record taken from an amphibious truck operating over a firm sand bottom, in about 3-ft waves, is shown in Fig. 4.

3. Operation Over Soft Mud Bottoms.—The strength and sharpness of the echo returned by the bottom depend on the relative speed of sound in the water and in the bottom material. This speed difference is relatively great between rock, sand or gravel, and water; and a sharp, forceful echo is reflected from such bottoms. A well-consolidated mud bottom will also return a sharp, forceful echo; however, the various gradations of mud bottoms, from very liquid muds practically in suspension to the well-consolidated bottoms, present another picture. A comprehensive testing of echo sounders over mud bottoms was made in 1941 by the Philadelphia (Pa.) District of the Corps of Engineers.

The tidewater section of the Delaware River (from Philadelphia to the sea) is in effect a great mud flat, the surface of which is being constantly swept by the ebb and flood of the tidal currents. The maintenance of the ship channel from Philadelphia to the sea involves continual dredging operations in, and surveys of, the channel. A study of the bottom materials has shown that frequently a well-consolidated mud bottom exists which is in turn overlain by several feet of less dense mud in a semiliquid state, locally called "fluff." In determining the dredging requirements and quantities moved, an accurate and consistent method of determining the bottom elevation is very desirable.

The test made on March 26, 1941, by the Philadelphia District involved among other things a set of simultaneous soundings by lead line and echo sounder and a study of the density of samples of the mud bottom taken at various elevations in the same area.

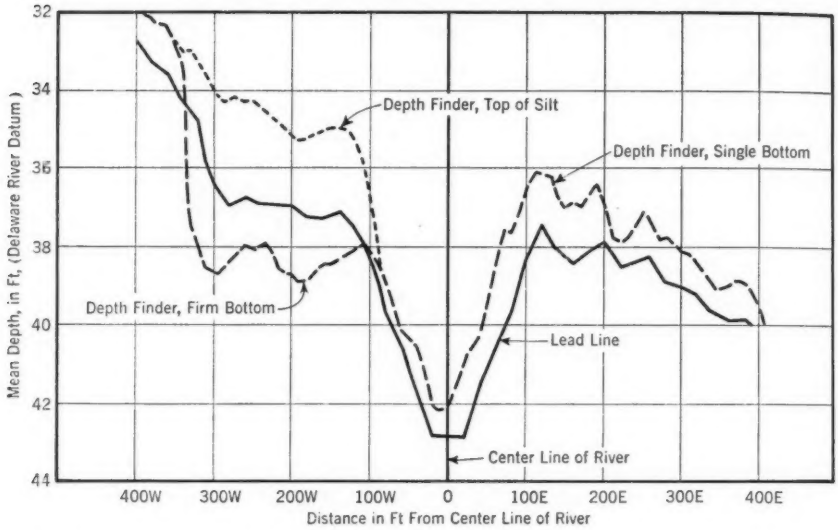

FIG. 5.—COMPARISON OF PROFILES BY LEAD LINE AND ECHO SOUNDER; STATION 193+108, DEEPWATER POINT RANGE, DELAWARE RIVER

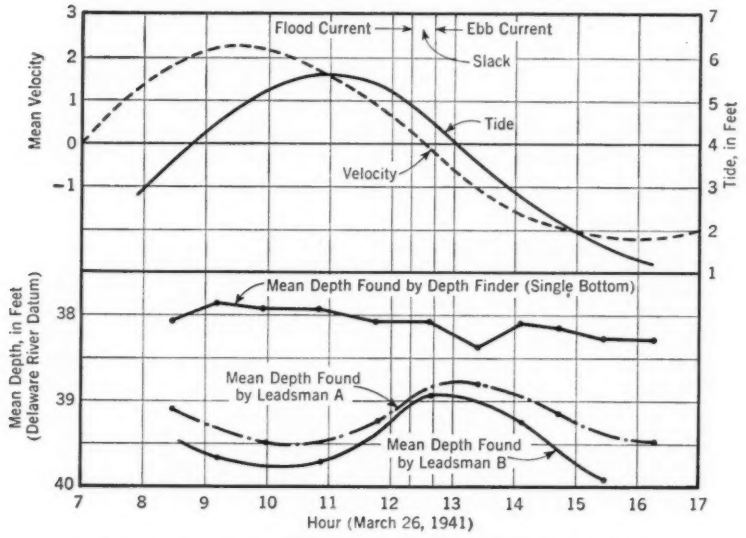

FIG. 6.—EFFECT OF THE VELOCITY OF TIDAL CURRENTS ON THE AVERAGE SOUNDINGS OVER FIRM MUD BOTTOM

Percentage of Time Departure From Average is Greater Than

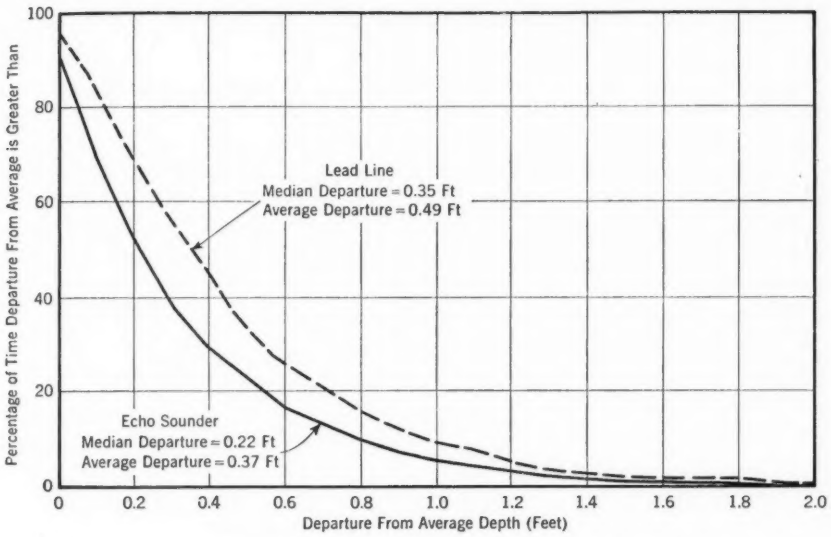

FIG. 7.—FREQUENCY-MAGNITUDE STUDY OF DEPARTURE OF INDIVIDUAL SOUNDINGS FROM THE AVERAGE OF ALL COMPARABLE SOUNDINGS OVER MUD BOTTOM

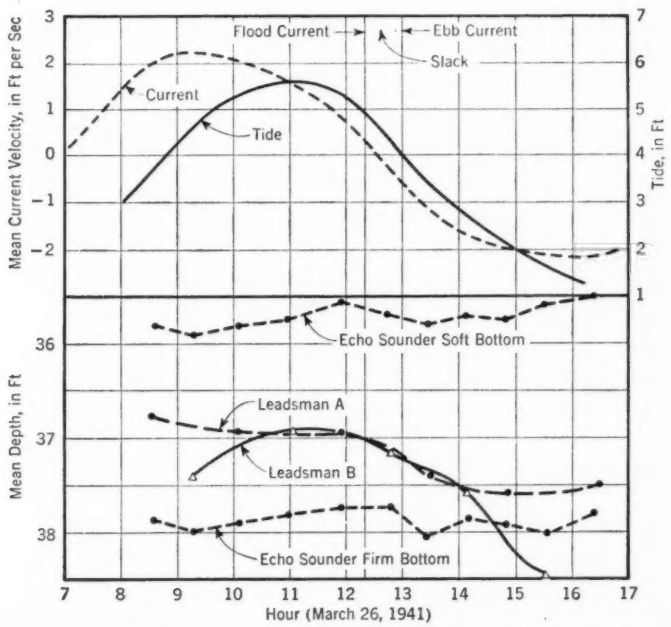

FIG. 8.—EFFECT OF VELOCITY CURRENTS ON AVERAGE SOUNDINGS OVER AN AREA OF SOFT MUD UNDERLAIN BY A FIRM MUD BOTTOM

In taking the lead line soundings, two experienced leadsmen using a 10-lb lead were employed, and they alternately sounded the same range (one, 5 times and one, 6 times) over a period of $8\frac{1}{2}$ hours. Concurrently, the same range was sounded by an echo sounder 33 times. The results of the soundings were averaged and the profiles resulting from the two methods were compared; this comparison is shown in Fig. 5. It is to be noted that over part of the area the echo sounder indicated a double bottom, the two being approximately 4 ft apart. In other sections of the profile, only one bottom was indicated by the echo sounder.

A study of Fig. 5 shows that the lead line was not consistent in its indication of depth to firm bottom. Over the east side of the range, where the echo sounder indicated a single, fairly firm bottom, the lead sank into the bottom

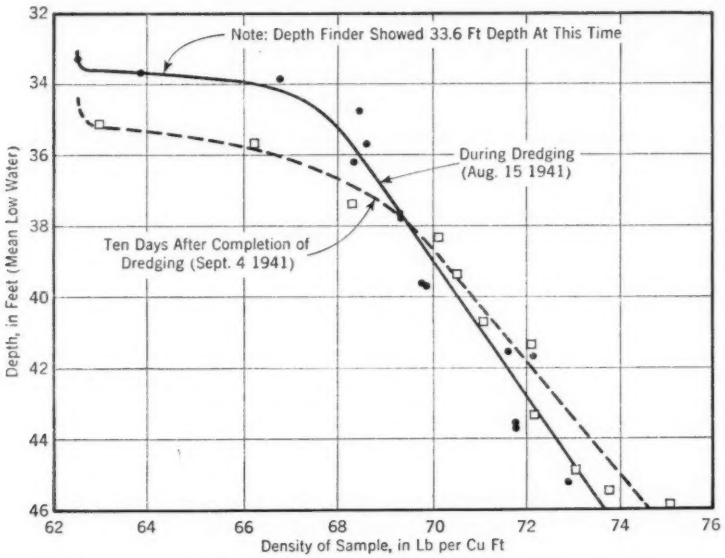

FIG. 9.—CHARACTERISTICS OF THE BOTTOM MATERIAL AT DEEPWATER POINT (STATION 187+650), DELAWARE RIVER

on an average of about 1 ft. On the west side of the channel where a double bottom was indicated by the echo sounder, the lead sank into the upper bottom generally from $1\frac{1}{2}$ ft to 2 ft and was still 1 ft or 2 ft above the lower and(firmer) bottom.

The analysis of the lead line soundings over the east half of the channel where a fairly firm mud bottom was found shows a personal factor to be in evidence in that leadsman A consistently found less depth than leadsman B; over the entire period the average difference was about 0.65 ft, the difference being about 0.3 ft at slack water and 1.0 ft at strength of current. This variation with current strength indicated that the bowing of the sounding line was definitely a factor in the accuracy of the lead line soundings. On the other hand, the echo sounder is free from this influence. This is shown in Fig. 6, in which the tide level, current strength, lead line soundings, and echo soundings

are plotted. At each point the soundings represent the average depth over the easterly 400 ft of the profile. Each plotted point on the curve, "Mean Depth Found by Depth Finder," represents the average of three runs.

Assuming the average profile indicated by the lead line soundings as a base, the error for each individual lead line sounding was calculated and summarized.

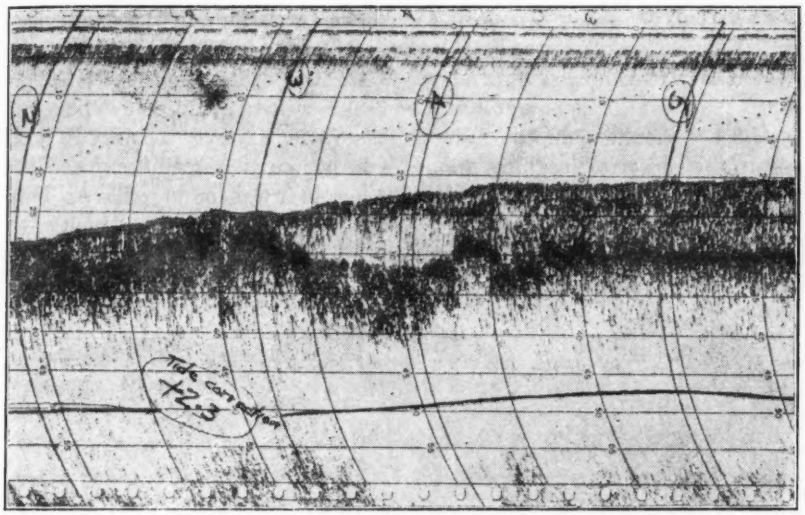

FIG. 10.—ECHO SOUNDER RECORD, RARITAN RIVER CHANNEL IN NEW JERSEY, TAKEN ABOUT 3 MONTHS AFTER DREDGING

The average error was found to be 0.49 ft over the east side of the channel. Using the average echo sounder profile as a base, a similar analysis was made of the echo sounder record, and this analysis showed an average error of 0.37 ft. The distribution of errors for both methods of sounding are shown in Fig. 7.

An analysis of the average lead line and echo sounder depths over the west half of the channel (400 ft) where the double bottom was found is shown in Fig. 8. The soft bottom area occurred from 80 ft to 350 ft west of the center line. The findings are in general similar to those shown in Fig. 6.

The project width of the Delaware Ship Channel is 800 ft. Over a mile of channel, uncompensated errors of as low an order as 0.1 ft will introduce an error in yardage computations of approximately 15,000 cu yd of material. Thus, uncompensated errors of as little as 0.1 ft assume some importance in calculations relative to dredging activities.

The lead line appears to have at least three inherent sources of error which might introduce uncompensated errors of 0.1 ft or even much greater: (*a*) The bowing of the lead line due to the pressure of the currents; (*b*) an error in judging the instant the lead line becomes plumb; and (*c*) the sinking of the lead by varying amounts in the soft bottom.

The echo sounder record is free from the influence of errors *a* and *b* but may be subject to error in interpretation due to variations in the consistency of the bottom material. A study of the bottom material in the Delaware River at a

point near the test sounding range, however, indicates that the error in the sounder record should not be excessive from this cause in this area. In studying the bottom materials a set of bottom material samples was taken at progressively increasing depths from the relatively clear top water, down through the fluff, and on down to the firm bottom, the fluff being about 10 ft thick in this area. A plot of the analysis of these samples is shown in Fig. 9. This plate shows two curves, one taken during dredging operations in the area and the other 10 days after dredging had been completed in the area. Both curves show a rather pronounced upper level of the fluff where the density changes abruptly from that of clear water at 62.4 lb per cu ft to about 66.5 lb per cu ft in about a 0.4-ft change in depth. The increase in density over the next 10 ft or so is essentially uniform, reaching about 74 lb per cu ft immediately above the firm bottom. The firm bottom material below 46 ft was found to have a density of approximately 92 lb per cu ft. These well-defined increases in density at the interface between the clear water and the top of the fluff and at the interface between the bottom of the fluff and the relatively firm bottom, of course, are

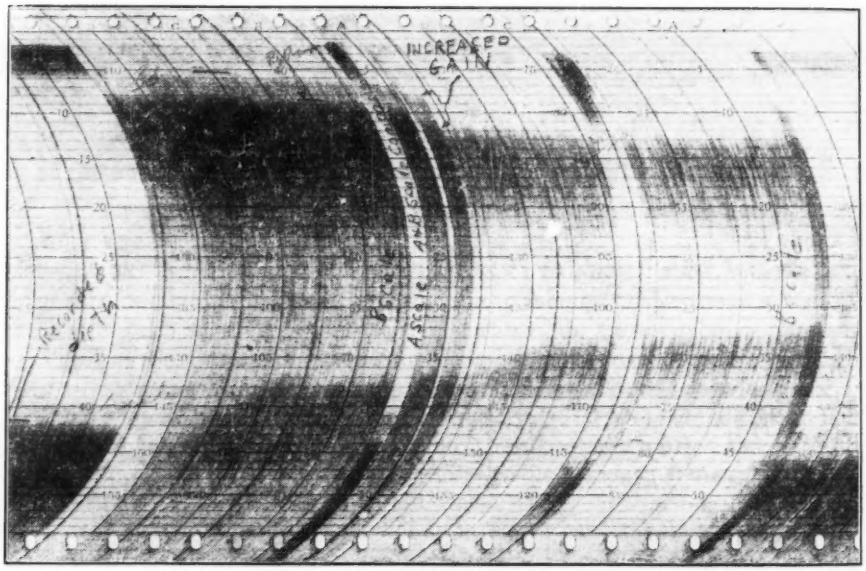

FIG. 11.—ECHO SOUNDER RECORD, CLEAR LAKE, LAKE COUNTY, CALIFORNIA, SHOWING THREE BOTTOM LAYERS

responsible for the well-defined record of these interfaces which are found on the echo sounder recorder.

Although the foregoing discussion of soft bottom areas concerns specifically conditions in the Delaware River in the area in which the observations were made, it is believed reasonable to assume that the findings might have a degree of application to other areas with soft bottoms. However, under conditions that depart significantly from the conditions mentioned, similar studies might

well be justified to determine the true significance of the echo sounder record. For instance, silting resulting from flocculation at the interface between fresh water and sea water might exhibit significantly different density characteristics, as might silt settling in a large reservoir where it was relatively undisturbed by waves and strong currents. The observations at Deepwater Point were taken in the tidal part of the Delaware but upstream from the influence of the salt water wedge.

Echo sounder records from the Raritan River, New Jersey, near New York Harbor, are shown in Fig. 10. The silt in this area was freshly deposited over a recent dredge cut and the line of demarcation can be clearly seen. The solid bottom of the dredged channel is shown at a depth of about 30 ft, overlain by the more recent deposit of silt. Fig. 11 shows a record furnished by the USCGS taken in Clear Lake, California. Here the silt has accumulated rather slowly, although two definite layers are indicated. Fig. 11 also indicates the effect of amplifier-gain setting on a determination of the bottom from echo sounder charts in this type of silt; in this case the topmost layer of silt was detected only with the high gain setting on the amplifier.

Summary

Echo sounders are now generally accepted in the field of hydrographic surveying as tools that promote accurate and rapid coverage of the survey area. Certain limitations in accuracy and application are present which should be understood by the user. The use of echo sounders over areas with steep side slopes or soft mud bottoms may require careful interpretation of the record to determine the significance and magnitude of certain features of the record which might otherwise be interpreted incorrectly. Supersonic frequency sounders are preferred to those operating at sonic frequencies because of better definition of the bottom resulting from a smaller sound cone and because of comparative freedom from interference from extraneous noises.

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